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Historical cartography as a tool to study urban change. The case of Garriga i Roca's *quarterons*

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Abstract

In the year 1858 the Barcelona City Council commissioned the architect Miquel Garriga i Roca with the creation of a topographic map of the city confined within the city walls. As a result he produced 119 very detailed maps with a scale of 1:250 which are known as the “Quarterons Garriga i Roca”. Due to their high level of detail and geometric quality these plans are a window to the past which can be used by scholars to study how Barcelona was. By using GIS these maps can be integrated with current cartography and therefore analyse in detail how the city's urban fabric has changed in the last 150 years. By using a series of selected quarterons this paper explores which is the best method to integrate past and current cartography and which challenges must be overcome in order to do it successfully.

Keywords: Quarterons, Barcelona, GIS, Historical Cartography.

Resum: *Cartografia històrica com a eina per a l'estudi urbà. El cas dels quarterons de Garriga i Roca*

L'any 1858 l'Ajuntament de Barcelona va encarregar a l'arquitecte Miquel Garriga i Roca que realitzés l'aixecament d'un plànol topogràfic de l'interior de la ciutat. Aquest, va elaborar una sèrie de 119 plànols amb una escala de gran detall, 1:250, que són coneguts com els “Quarterons Garriga i Roca”. Aquests plànols suposen una finestra a la Barcelona dins muralles de mitjans del segle XIX, ja que el seu elevat nivell de detall i la seva qualitat geomètrica permeten atansar la trama urbana i cadastral barcelonina a l'investigador contemporani. Mitjançant l'ús dels SIG es pot integrar aquesta cartografia històrica amb mapes actuals per tal d'analitzar com ha evolucionat l'urbanisme del districte municipal de Ciutat Vella

en els darrers 150 anys. En aquest cas, mitjançant l'ús d'una sèrie de quarterons pilot, s'explora quin és el millor mètode per a assolir una integració satisfactòria entre ambdues bases cartogràfiques i quins reptes cal superar per a fer-ho amb èxit.

Paraules clau: quarterons, Barcelona, GIS, cartografia històrica.

Resumen: *Cartografía histórica como herramienta para el estudio urbano. El caso de los cuarterones de Garriga i Roca*

El año 1858 el Ayuntamiento de Barcelona encargó al arquitecto Miquel Garriga i Roca que realizara el levantamiento de un plano topográfico del interior de la ciudad. Éste elaboró una serie de 119 planos en una escala de gran detalle, 1:250, que son conocidos como los “Cuarterones Garriga i Roca”. Estos planos suponen una ventana a la Barcelona del interior de las murallas a mediados del siglo XIX, ya que su gran detalle y su calidad geométrica permiten acercar la trama urbana y catastral barcelonesa al investigador contemporáneo. Mediante el uso de los SIG se puede integrar esta cartografía histórica con mapas actuales para analizar cómo ha evolucionado el urbanismo del distrito municipal de Ciutat Vella en los últimos 150 años. En este caso, mediante el uso de una serie de cuarterones piloto, se explora cuál es el mejor método para lograr una integración satisfactoria entre ambas bases cartográficas y qué retos hay que superar para hacerlo con éxito.

Palabras clave: cuarterones, Barcelona, GIS, cartografía histórica.

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Historical cartography, GIS and urban change

A plethora of maps were created before the Digital Revolution started and, even though many of them have succumbed to the toll of time, thousands are still preserved in libraries, universities or private collections. The information held within these documents is of invaluable importance as in many cases it is the only source available to study certain areas or topics. All this documentation offers a window to the past and, consequently, it is of great interest not only to researchers of many disciplines but also to the general public, an interest which keeps on growing as new applications are developed. When these maps are associated with modern digital techniques they can be used as a way of knowing how the world has changed in the last few hundred years and compare it with how it is today.

The combination of historical cartography and Geographical Information Science (GIS), while being recent, is not something new. For some years now geographers, historians, librarians and other researchers interested in studying the past in a spatial way have used digital copies of antique maps together with GIS to obtain new information from them. The level of analytic complexity

however has progressively increased, reaching the limits of what can and cannot be done with historic maps. Initially, digitising –i.e. scanning or digitally photographing– an old map was considered something new, so a lot of effort has been put into obtaining digital copies of paper based maps in a herculean task which is still carried on by libraries all over the world. This effort, combined with the proliferation of digital repositories of historical cartography available on-line, such as the digital map library of the Cartographic Institute of Catalonia (Institut Cartogràfic de Catalunya, 2014), has had two positive outcomes. On one hand it has been a way of digitally preserving documents which otherwise could physically disappear, while on the other it has facilitated the distribution and availability of said maps.

The increasing availability of digitised historical maps has spurred their use by researchers, who have gone a step further and have been able to create new and interactive ways of dealing with the information held in these documents. By georeferencing first and then vectorising the information held in antique maps distinct features can be highlighted and new information can be even generated. In the case of Catalonia early examples have mostly been limited to working with rural areas using cadastral maps which allow studying land use and land ownership change. Two prime examples, one of Sant Martí de Provençals (Font Casaseca, 2008) and another about the Maresme shire (Parkeris, 2008), are worth being mentioned. Both examples showed how land use has changed in the last 150 years, but, like the original maps they worked with, they were planimetric. A few years later orography was introduced into the treatment of historic maps, in this case exploring the former town of Horta (Nobajas & Nadal, 2012). In this example the information obtained from a cadastral map from 1861 was combined with a Digital Elevation Model (DEM), something which allowed observing the altitudinal evolution of land uses. In addition to that, results were also published using an interactive web application which allowed not only researchers, but also the general public to observe a 3D recreation of the town's past (Nobajas, 2012).

All these examples, even if advanced and relevant, have so far ignored the urban fabric and have only focused on the rural side of towns. Villages and inhabited locations have been treated as a homogenous area and no specific or detailed studies have been carried out about the built up area. The reason why this has been this way is due to a series of characteristics which are inherent to historical urban cartography such as difficulty, scale, inadequate current cartography and high variability:

- Difficulty: Rural historical cartography mainly deals with land property and land use, sometimes adding additional information such as hydrography, paths or relief, which are represented using relatively simple geometrical shapes. On the other hand urban cartography, while also commonly dealing with land property and land use, depicts the complexity of the urban fabric, with streets, boulevards, fountains or even lampposts. All

these features make working with them quite challenging, as there are many elements of interest which need to be properly georeferenced and digitised.

- Scale: While historical urban cartography can be found using a large variety of scales it was not uncommon for map commissioners to ask for very detailed plans. High levels of detail give current researchers abundant information about the past, but they also make potential errors more notorious. Since map making techniques were not as advanced in the past, error is something which needs to be taken into consideration when dealing with historical cartography. Due to the fact that rural historical is usually represented using smaller scales, error, even if important, is not as crucial. For example, a real world measurement error of two metres would equal to a negligible 0.04 cm on a 1:5000 rural plan, but to a noticeable 0.8 cm on a 1:250 urban plan. This means that error is much more relevant in urban maps than in rural ones, something which may hinder the functionality of current historical urban cartography digital applications.
- Inadequate current cartography: In order to adequately georeference historic urban cartography it is necessary to have detailed current urban geographic databases. These contemporary maps should be of a similar scale of those to be referenced and have a high level of accuracy. Unfortunately quite often current maps are not as accurate as it would be expected and add a new source of error which needs to be taken into account as well.
- High variability: Apart from the issues already mentioned, in order to successfully georeference a historic map it is necessary to have a series of common points between the past and the current map, the more the better. The characteristic dynamism of urban areas makes this task more difficult as common places tend to be difficult to find. Moreover in many occasions what appear to be adequate reference points turn out to be unsuitable. A wider sidewalk, a newly aligned building or a redesigned edification can lead to mistakes which introduce new sources of error. It is therefore of paramount importance to be aware of the history of the area to minimise the impact those changes can have when working with historic urban cartography.

Even with all these limitations and issues, transforming historic urban maps into digital representations is possible, as several existing examples prove. A simple yet effective system created to combine historical and current cartography was recently created using maps from Madrid (Consejo Superior de Investigaciones Científicas, 2013). Even if this system is relatively simple and only uses maps from the 20th century it is a very good starting point of what it can be achieved by combining former and current cartography. Another

example, this time hugely ambitious, was created using the early 19th century Plan Vasserot of Paris (Noizet, Bove *et al.*, 2013). The project was carried out by a combination of researchers from different fields of knowledge who created a very useful web application (fig. 1) which allows the user to explore how Paris was in the past with a great level of detail (ALPAGE, 2013).

Figure 1. Screenshot of the ALPAGE web application



Source: ALPAGE (2013)

In the case of Barcelona, even if a wealth of historic cartographic information about the city exists, no comparable applications have been implemented. This situation is not ideal as many researchers use Barcelona as their study area and would find similar resources very useful for their work. Moreover the general public shows quite an interest regarding historical information about how cities and places were like in the past (Werner, 2014), so an application like the one in Paris but applied to Barcelona it is likely to have an impact at several levels. Barcelona has many maps which could be used to replicate or even improve the ALPAGE system, but in this paper only the map known as “*quarterons*” (1859-1862), by Garriga i Roca, will be used as an example. The *quarterons* are an ideal candidate to being converted into a digital interactive system because they have a very detailed scale, have many minutiae which other maps lack and depict the Barcelona right before the city walls were demolished.

Garriga i Roca and his “*quarterons*”

Miquel Garriga i Roca (1808-1888) was a Catalan architect who had an interest in cartography and consequently was commissioned to develop several

cartographic projects. After finishing his studies in 1837 and becoming an architect the year after (Montaner, 1990), Garriga i Roca started his career as a cartographer in the year 1840, when he was commissioned with the delimitation of the limits between the towns of Mataró and Argentona (Nadal, 2011). After this first map making job he produced several other cartographic documents, such as the map of the Port of Barcelona (1852) or the proposal for the expansion of Barcelona outside its city walls (1854). Due to all this experience it is not surprising that in 1858, after some discussion and once other options were discarded (Nadal, 2011), Barcelona's city council commissioned Garriga i Roca as the author of the Geometrical Plan of Barcelona and the Surroundings (Sagarra i Trias, 1996). The map, commonly known as the "Plànol de Barcelona", was in reality more than just a map, it was a series of documents, most of them cartographic, which initial purpose was to help with the correct aligning of buildings on the streets (Nadal, 2011). In order to fulfil the task commissioned by the City Council, Garriga i Roca created several cartographic documents, of which three are worth mentioning here. The first one was the *Plano topográfico-geométrico de la ciudad de Barcelona*, a map of all the city finished in the year 1862 and created at a scale of 1:2000. The second document was a series of blueprints of all public and religious buildings of the city at a scale of 1:100, plans which nowadays are of paramount importance as they give information about how many buildings which have disappeared or are still standing were 150 years ago. The third type cartographic documents produced by Garriga i Roca were the *quarterons*, which could be translated as *quarters*, and in which this paper focuses.

The quarterons are a series of maps at a scale of 1:250 which are the most detailed depiction the city at the time, but while 119 have been preserved and can still be consulted, some have been lost (Nadal, 2011). Even though, apart from a small area around the Northern limit of the Raval neighbourhood, all 19th century Barcelona can be seen through the work of Garriga i Roca. The quarterons are handmade, highly chromatic, very detailed and provide a wealth of information. All urban plots are measured and the relative age of the buildings is coded using a series of colours, which gives an idea of the type of buildings existing in each area. Moreover, those buildings which are of interest –mainly public and religious constructions– are represented with an extreme level of detail and include the distribution of their inner spaces. Regarding public space, a never-ending list of features is provided, including fountains, squares, patios, gardens, canals, jails, stations, schools or post offices, just to mention a few. It is therefore an invaluable source of information about the city's past which should, and hopefully will, be used to gain a broader knowledge of the past.

Out of the 119 available quarterons, four of them were randomly chosen to analyse the potential they had when combined within a GIS. The selected quarterons are quarteró number 35, which is located between the streets Por-

tal de l'Àngel, Duran i Bas, Montsió and Magdalenes; quarteró 43, which is between the Plaça Nova and Duran i Bas; quarteró 53, which corresponds to the former Convent dels Àngels block, and quarteró 62, which is enclosed by the streets Portaferrixa, Petritxol and El Pi (fig. 2). These quarterons are a good sample of Garriga i Roca's work since they represent areas which have different characteristics and which have had evolved differently. While quarteró 62 was mainly occupied by residential buildings quarteró 53 was almost completely filled by a convent which does not exist nowadays. Quarterons 35 and 43, on the other hand, have had suffered some dramatic changes while maintaining some areas unchanged. All these differences will put the proposed method to the test and prove if when combined with the quarterons the newly created information is relevant. Finally, since they represent different areas of different characteristics conclusions drawn by using them should be applicable to the rest of the quarterons and consequently the rest of the city.

Figura 2. Location of the selected quarterons



Source: Author's work. Imagery from Google 2013

Challenges when combining diachronic maps

Combining historic maps with current geographic databases is not an easy task and, more importantly, it is not always possible. Cartographic methods have dramatically improved and many older maps cannot compare with the geographical precision modern maps have, meaning that their concurrent use will be either impossible or flawed. Before any work with historical cartography is carried out it is necessary to test the adequacy of the older maps when com-

pared to modern ones, as poor compatibility could render the historical ones not fit for purpose. Garriga i Roca's quarterons are no exception, and even if they appear to be adequate they must be tested for suitability.

The method used is similar to that previously used for another map of the Barcelona area, the 1861 Horta map by Joan Serra (Nobajas, 2011). The first step is to digitise the selected maps, a process which can be done by photographing or by scanning the document, being the latter method better as it does not potentially distort the image as much as the first one (Nobajas & Nadal, 2012). Once the document is available in a digital form it can be georeferenced using up-to-date cartography and identifying common points which can be used to give current coordinates to the older document. In this case two up-to-date background datasets were used, the cadastral map for Barcelona at a scale of 1:500 (Dirección General del Catastro, 2014) and the orthophotograph of the area at a scale of 1:2500 with a stated maximum error of 25 cm in reality (Institut Cartogràfic de Catalunya 2010). Both datasets are provided by official institutions which create cartography allegedly to the highest standards. However, when they are combined together they do not match properly, as figure 3 shows. This discrepancy can be due to several reasons, but according to the institution responsible of the aerial imagery it is because rectifying rooftops it is quite expensive (Institut Cartogràfic i Geològic de Catalunya, 2014) and it is only done in certain locations, so in this case only building footprints were rectified (Institut Cartogràfic i Geològic de Catalunya, 2014). In any case it is clear that in order to have results as robust as possible it was necessary to use only a modern dataset and due to its higher precision –1:500 vs 1:2500– the cadastral map was selected.

Figura 3. Discrepancy between two modern cartographic datasets



Source: Author's work from Dirección General del Catastro 2014, Institut Cartogràfic de Catalunya 2010.

Once an appropriate reference dataset is chosen it is possible to start the georeferencing process with each quarteró. In order to georeference a map a minimum of three common points are necessary, but in order to achieve the best results more may be necessary (ESRI, 2013). The main challenge in this case is that it is difficult to find precise points which exist in both maps as many buildings have been demolished and built up again in the same place but with slightly different shapes or limits, something which can trick the georeferencer into assuming that two points correspond to the same feature when that is not true. The same applies to streets, sidewalks or even public buildings. However, it was possible to find an adequate amount of control points in all analysed quarterons, meaning that all of them were successfully placed within a current reference system.

With all pilot quarterons properly georeferenced it was possible to compare the cartography drawn by Garriga i Roca 150 years ago with current geographic databases. However, results were not as successful as initially expected because during the georeferencing process historic maps became, even if marginally, deformed. The level of deformation, which is a well-known issue when working with historical cartography (Bitelli & Gatta, 2011), was not very important, but due to the level of detail of the historic map at hand it was still relevant and not adequate for the initial purpose of the research, to quantitatively measure urban change in the city of Barcelona. Due to the deformation it is not possible to precisely measure distances or surfaces, so the comparison of different urban factors becomes quite limited. The causes of this error are not easy to pinpoint, but some hypothesis can be stated to try and explain them. As it has been already noted, the current cadastral dataset and the aerial imagery used do not overlap effectively, so it is likely that, even if slightly, one, the other or both have a margin of error that when using them at the quarterons' scale 1:250 becomes quite notorious. There is however potential another source of error, the quarterons themselves. The maps were made using mid-19th century techniques and methods, so it is plausible that either the measurements or the drawing of the maps were not fully correct. These potential inaccuracies could be exacerbated by the fact that the historic maps are paper based, which means that depending on the conditions in which they were stored the paper could have been deformed (Rahnemoonfar & Antonacopoulos, 2011). This could be the reason why in some quarterons scale bar divisions are not equidistant, something which at times it is noticeable to the naked eye. Scale bars which present such deformation do not have consistent divisions and present different lengths when they should all be equal, something which could be due to the physical deformation of the document. Very recent methods are being developed to digitally fix these issues (Pal, Schüller *et al.* 2014), but for the time being paper deformation is an issue which cannot be easily solved.

Even if this cumulative sum of imprecisions hinders the potentially very powerful urban analysis which could be carried out by analysing the historic maps in detail, the quarterons can still provide a wealth of information about how Barcelona was 150 years ago. By applying the aforementioned process of digitalisation and georeferencing to all four pilot quarterons and combining them with current cadastral cartography.¹

Quarteró 35

The area depicted by quarteró 35 (fig. 4) has not experienced dramatic changes since Garriga i Roca made his survey. Streets surrounding it almost have the same design and most current cadastral limits correspond to properties delimited in the 19th century. The biggest change is that an area to the East of the block which was built up in the 1860s was demolished to create a little square now known as “Plaça dels Peixos”. Finally, a private garden was lost when the Fundació Balmesiana built its current headquarters during the 20th century (Fundación Balmesiana, 2004).

Figura 4. Quarteró 35 and current cadastral limits



Source: Author's work from Direcció General del Catastro (2014) and Fons Cartogràfic de l'AHCB

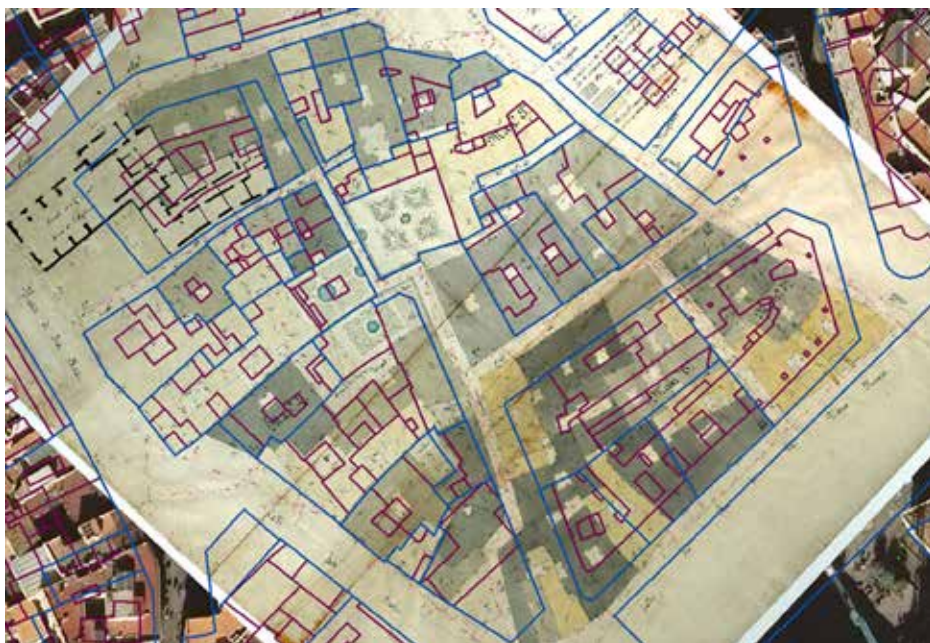
Quarteró 43

Quarteró 43 (fig. 5) presents important changes in the urban fabric, with many buildings, streets and public spaces having changed since the map was drawn. Regarding the street network, several streets have disappeared, while others have been created and some have been widened to oxygenate

1. In all maps blue lines represent current cadastral limits while purple lines represent built up areas.

the area. New public spaces were developed due to the demolition of existing buildings, like the “Plaça del Vuit de Març” or la “Plaça d’Iside Nonell, consequently reducing the built up density of the area. Public buildings were also modified or demolished. For example, the School for Blind People –formerly Saint Cajetan’s Church– was demolished in order to create building nowadays used by the City Council and a small square. However, the most dramatic change can be found on the Sout-East corner of the quarteró, where two full blocks of buildings were demolished. The area, one of the limits of the Plaça Nova and right in front of the Cathedral, was flattened and rebuilt using different cadastral limits than the ones present before, which resulted in wider surrounding streets, but also the loss of Sallent Street.

Figura 5. Quarteró 43 and current cadastral limits.



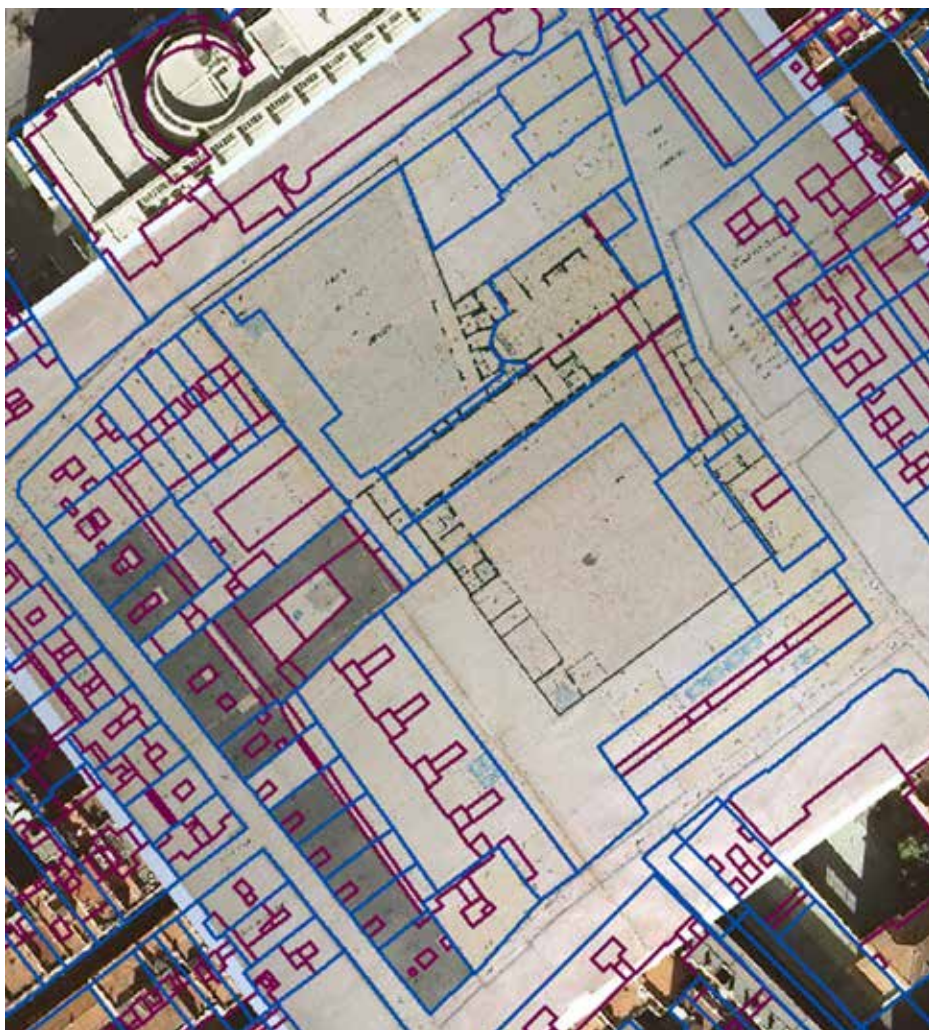
Source: Author's work from Direcció General del Catastro (2014) and Fons Cartogràfic de l'AHCB

Quarteró 53

Perhaps quarteró 53 (fig. 6) presents the most dramatic changes of all four pilot quarterons. This quarteró was mostly occupied by the “Convent dels Àngels”, a very large religious building about which Garriga i Roca's map provides very detailed and precise information since the inner structure and distribution of the complex was depicted in the plan. The convent was partially demolished and the whole area was radically changed during the following urbanisation process, something which

means that the land use has experienced big changes (Bayo 2001). Only a small proportion of the convent remains, most especially the chapel, and the area has been redeveloped into open public space and the Contemporary Art Museum of Barcelona (MACBA). Apart from this major urban conversion the rest of the quarteró has not experienced such dramatic changes.

Figura 6. Quarteró 53 and current cadastral limits



Source: Author's work from Direcció General del Catastro (2014) and Fons Cartogràfic de l'AHCB

Quarteró 62

This quarteró (fig. 7) presents very small and subtle changes as its urban plan has remained quite stable in time. Streets are mostly unaltered –in-

cluding private passages— and the built up area is mostly as it was over 150 years ago. The only significant differences from a land use point of view are that some small formerly green areas are now either built up or paved, a few buildings have been demolished and some constructions have changed their use. This is therefore a prime example of how some areas of Barcelona have remained mostly oblivious to the dramatic urban changes the city has experienced since the quarterons were drawn.

Figura 7. Quarteró 62 and current cadastral limits



Source: Author's work from Direcció General del Catastro (2014) and Fons Cartogràfic de l'AHCB

Future objectives

The test of all four pilot quarterons has been successful overall as their combination with current cartography has allowed performing qualitative analysis of the urban evolution of the city. By combining current and past cartography, the usefulness of the latter is augmented and its dissemination and its understanding can be greatly improved, but it is necessary to be aware of the existing limitations present in the proposed method in order to minimise them. While some sources of error have no present solution and have to be assumed as unavoidable and therefore they will persist, other factors can be reduced in order to improve the final result and move from a qualitative perspective to a quantitative one. It is therefore necessary to find ways of reducing said error in order to continue the work with the remaining 114 untreated quarterons or nonrelated maps, but in the meanwhile limitations need to be acknowledged and tackled when possible.

Once ways of minimising the imprecisions of the process have been solved, the really arduous task of vectorising all quarterons will start. This process, due to the characteristics of historical cartography, is currently manual, so it implies hundreds of work hours in order to digitise significant surfaces. It is therefore required to look for solutions which will automate the vectorising process and will consequently ease the necessary workload to achieve final results. If this automatisation is achieved it could be applied to many other maps, something which would consequently benefit all those working with historical cartography.

Regardless of the method used, once error and vectorisation issues are solved it should be possible to recreate all quarterons digitally and consequently distribute them on-line. If the process has been correctly performed, it would be possible to study and quantify how Barcelona's urban fabric has changed and many factors could be studied, such as public land ratios or plot size, just to mention a couple. Moreover, when combined with other documentation a 3D recreation of the 19th century city could be developed, greatly improving the level of understanding of Barcelona's past. In the meanwhile however, data contained within the quarterons will have to be treated in a qualitative way, which can suffice for certain purposes, but it is a stage should be overcome.

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